NCEP CFS Status and Future Plans

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Overview

• Current (CFS-v1) description and status
• CFS Reanalysis and Reforecast (CFSRR → CFS-v2)
  – Atmosphere
  – Ocean
  – Land surface
  – Sea ice
• Future development (CFS-v3)
  – A-O-L-S
Seasonal to Interannual Prediction at NCEP Operational System since August 2004 (CFS-v1)

Ocean Model
MOMv3
quasi-global
1°x1° (1/3° in tropics)
40 levels

Atmospheric Model
GFS (2003)
T62 (~200 km)
64 levels

Climate Forecast System (CFS)

Reanalysis-2
3DVAR
T62L28
OIv2 SST
Levitus SSS clim.

Daily Coupling

GODAS (2003)
3DVAR
XBT
TAO
Triton
Pirata
Argo
Salinity (syn.)
TOPEX/Jason-1

Ocean reanalysis (1980-present)
provides initial conditions for retrospective
CFS forecasts used for calibration and research

Funded by NCPO/OCO

Stand-alone version with a 14-day lag
updated routinely

“Weather & Climate” Model
Number of Temperature Observations per Month as a Function of Depth
1. High resolution data assimilation
   - Produces better initial conditions for operational hindcasts and forecasts (e.g. MJO)
   - Enables new products for the monthly forecast system
   - Enables additional hindcast research

2. Coupled data assimilation
   - Reduces “coupling shock”
   - Improves spin up character of the forecasts

3. Consistent analysis-reanalysis and forecast-reforecast for
   - Improved calibration and skill estimates

4. Provide basis for a future coupled A-O-L-S forecast system running operationally at NCEP (1 day to 1 year)
   - (currently in parallel testing for “GFS” 1-14 day prediction)

Funded by NCPO/CDEP
CFSRR Components

- **Reanalysis**
  - 31-year period (1979-2009 and continued in NCEP ops)
  - Atmosphere
  - Ocean
  - Land
  - Seaice
  - Coupled system (A-O-L-S) provides background for analysis
  - Produces consistent initial conditions for climate and weather forecasts

- **Reforecast**
  - 28-year period (1982-2009 and continued in NCEP ops)
  - Provides stable calibration and skill estimates for new operational seasonal system

- **Includes upgrades for A-O-L-S developed since CFS originally implemented in 2004**
  - Upgrades developed and tested for both climate and weather prediction
  - “Unified weather-climate” strategy (1 day to 1 year)
# CFSRR Component Upgrades

<table>
<thead>
<tr>
<th>Component</th>
<th>Ops CFS</th>
<th>2010 CFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>1995 (R2) model 200 km/28 sigma levels</td>
<td>2008 model (upgrades to all physics) 38 km/64 sigma-pressure levels</td>
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<tr>
<td></td>
<td></td>
<td>Enthalpy-based thermodynamics Variable CO2 (historical data, future scenarios)</td>
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<tr>
<td></td>
<td>R2 analysis Satellite retrievals</td>
<td>GSI with simplified 4d-var (FOTO) Radiances with bias-corrected spinup</td>
</tr>
<tr>
<td>Ocean</td>
<td>MOM-3 60N – 65 S 1/3 x 1 deg.</td>
<td>MOM-4 ¼ x ½ deg. Coupled sea ice forecast model</td>
</tr>
<tr>
<td>Ocean data assim.</td>
<td>750 m depth</td>
<td>2000 m</td>
</tr>
<tr>
<td>Land</td>
<td>No separate land property analysis</td>
<td>Global Land Data Assim. Sys (GLDAS) driven by observed precipitation</td>
</tr>
<tr>
<td></td>
<td>1995 land model (2 levels)</td>
<td>2008 Noah model</td>
</tr>
<tr>
<td>Sea ice</td>
<td>Daily analysis</td>
<td>Daily hires analysis</td>
</tr>
<tr>
<td>Coupling</td>
<td>None</td>
<td>Fully coupled background forecast (same as free forecast)</td>
</tr>
</tbody>
</table>
One-day schematic of four 6-hourly cycles of CFSRR Global Reanalysis:

Atmospheric Analysis

Ocean Analysis

Land Analysis

Time
Testing with CMIP Runs (variable CO2)

**OBS** is CPC Analysis (Fan and van den Dool, 2008)

**CTRL** is CMIP run with 1988 CO2 settings (no variations in CO2, current operations)

**CO2** run is the ensemble mean of 3 NCEP CFS runs in CMIP mode
- realistic CO2 and aerosols in both troposphere and stratosphere

**Processing**: 25-month running mean applied to the time series of anomalies (deviations from their own climatologies)
Climate Forecast System V2

- Atmospheric Model
  - GFS (2007)
  - T382 64 levels

- Ocean Model
  - MOMv4
  - fully global
  - 1/2°x1/2° (1/4° in tropics)
  - 40 levels

- Land Model

- Ice Model

- GDAS
- GSI

- LDAS

- 6hr
- 24hr

- Ice Ext

- 6hr

- GODAS 3DVAR

- 6hr
Future Development

• What’s going on and what’s needed
  – Land surface
  – Ocean & Sea ice
  – Atmosphere
Noah LSM replaces OSU LSM in new CFS

- **Noah LSM**
  - 4 soil layers (10, 30, 60, 100 cm)
  - Frozen soil physics included
  - Surface fluxes weighted by snow cover fraction
  - Improved seasonal cycle of vegetation cover
  - Spatially varying root depth
  - Runoff and infiltration account for sub-grid variability in precipitation & soil moisture
  - Improved soil & snow thermal conductivity
  - Higher canopy resistance
  - More

- **OSU LSM**
  - 2 soil layers (10, 190 cm)
  - No frozen soil physics
  - Surface fluxes not weighted by snow fraction
  - Vegetation fraction never less than 50 percent
  - Spatially constant root depth
  - Runoff & infiltration do not account for subgrid variability of precipitation & soil moisture
  - Poor soil and snow thermal conductivity, especially for thin snowpack and moist soils

Noah LSM replaced OSU LSM in operational NCEP medium-range Global Forecast System (GFS) in late May 2005

Some Noah LSM upgrades & assessments were result of collaborations with CPPA PIs

Funded by NCPO/CPPA
CFSRR Reanalysis Land Component: Global Land Data Assimilation System (GLDAS)

- Applies same Noah LSM as in new CFS
- Uses same native grid (T382 Gaussian) as CFSRR atmospheric analysis
- Applies CFSRR atmospheric analysis forcing (except for precip)
  - hourly from previous 24-hours of atmospheric analysis
  - Precipitation forcing is from CPC analyses of observed precipitation
    - Model precipitation is blended in only at very high latitudes
- GLDAS daily update of the CFSRR reanalysis soil moisture states
  - Reprocesses last 6-7 days to capture and apply most recent CPC precipitation analyses
- Realtime GLDAS configuration will match reanalysis configuration
  - To sustain the relevance of the climatology of the retrospective reanalysis
- Applies LIS: uses the computational infrastructure of the NASA Land Information System (LIS), which is highly parallelized
Impact of Noah vs. OSU Land Models and GLDAS Initial Land States in 25-years of CFS Summer & Winter Reforecasts:

(Supporting CFS results will be presented by Ken Mitchell on Wed morning)

• Land surface model (LSM) for CFS forecast must be same as for supporting land data assimilation system (LDAS)

• Impact of land surface upgrade on CFS seasonal precipitation forecast skill for is positive (but modest)
  – Significant only for summer season in neutral ENSO years (and then only small positive impact)
  – Essentially neutral impact for winter season and non-neutral ENSO summers

• Differences in CFS precipitation skill over CONUS between neutral and non-neutral ENSO years exceeds skill differences between two different land configurations for same sample of years
  – Indicates that impact of SST anomaly is substantially greater than impact of land surface configuration
2009+ Land Surface Model Development

1 - Unify all NCEP model land components to use MODIS-based hi-res global land use with IGBP classes

2 - Improve global fields of land surface characteristics (vegetation cover, albedo, emissivity) using satellite data (with Joint Center for Satellite Data Assimilation)

3 - Enhance land surface subgrid-variability with high-resolution sub-grid tiles

4 - Increase number of soil layers (from 4 to about 10)

5 - Introduce dynamic seasonality of vegetation (to replace pre-specified seasonal cycle)

6 - Improve hydrology including addition of groundwater

7 - Add multi-layer treatment to snowpack physics

8 - Introduce carbon fluxes

Items 5-8 are being transitioned from the CPPA-funded work of PI Prof Z.-L. Yang and Dr. G.-Y. Niu of U.Texas/Austin
GODAS in the CFSRR

• Operational in 2010
• MOMv4 (1/2° x 1/2°, 1/4° in the tropics, 40 levels)
• Updated 3DVAR assimilation scheme
  – Temperature profiles (XBT, Argo, TAO, TRITON, PIRATA)
  – Synthetic salinity profiles derived from seasonal T-S relationship
  – TOPEX/Jason-1 Altimetry
  – Data window is asymmetrical extending from 10-days before the analysis date
  – Surface temperature relaxation to (or assimilation of) Reynolds new daily, 1/4° OIv2 SST
  – Surface salinity relaxation Levitus climatological SSS
  – Coupled atmosphere-ocean background
• Current stand-alone operational GODAS will be upgraded in 2009 to the higher resolution MOMv4 and be available for comparison with the coupled version
  – Updated with new techniques and observations
In the west, assimilating Argo salinity corrects the bias at the surface and the depth of the undercurrent core and captures the complex structure at 165°E.

In the east, assimilating Argo salinity reduces the bias at the surface and sharpens the profile below the thermocline at 110°W.

**Assimilating Argo Salinity**

Comparison with independent ADCP currents.

**Equatorial Mean Zonal Velocity**

**Equatorial Mean Zonal Velocity**

ADCP  GODAS  GODAS-A/S

D. Behringer
2009+ GODAS Activities

- Complete CFSRR
  - Evaluate ODA results
- Add ARGO salinity
- Improve climatological T-S relationships and synthetic salinity formulation
- ENVISAT data?
- Improve use of surface observations
  - Vertical correlations (mixed layer)
- Situation-dependent error covariances (recursive filter formulation)
- Investigate advanced ODA techniques
  - Experimental Ensemble Data Assimilation system (with GFDL)
  - Reduced Kalman filtering (with JPL)
  - Improved observation representativeness errors (with Bob Miller, OSU-JCSDA)
- Impact of the GODAS mixed layer analysis on subseasonal forecasting with the CFS. Augustin Vintzileos (EMC)
Sea Ice Analysis from CFSRR


CFSRR NH

ODAS NH

CFSRR SH

ODAS SH

Wenjie Wang
 CPC/IGPS/NOAA
Atmospheric Model

- Improve CFS climatology and predictive skill with improved physical parameterizations
  - Deep and/or shallow convection
  - Cloud/radiation/aerosol interaction and feedback
  - Boundary layer processes
  - Orographic forcing
  - Gravity wave drag
  - Stochastic forcing
  - Cryosphere
Summary

- **CFSRR → CFS-v2**
  - High resolution reanalysis
  - CO2 trend
  - Upgrades models and data assimilation
  - Foundation for coupled “earth-system” reanalysis

- **Beginning scientific development of CFS-v3**
  - A-O-L-S
  - Advanced data assimilation techniques
Thanks
Questions?